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Kenya Tsuge* Hideo Akamatsu†

Masayoshi Matsushita‡

*Okayama University,

†Okayama University,

‡Okayama University,

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Kenya Tsuge, Hideo Akamatsu, and Masayoshi Matsushita

Abstract

In the foregoing our methods of the grafting of tendon in finger used recently are presented. Namely, the proximal ends of tendon to be grafted are at first sutured by the embedding method of BUNNELL, and then the distal ends are fixed with our method we get the benefits of giving just appropriate tension to the tendon and also of reliable fixation. Finally the findings before and after operation on the two cases treated by our method are pictorially presented in Figs. 12 and 13.

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THE TENDON GRAFTING IN FINGER AND OUR METHOD

Kenya TSUGE, Hideo AKAMATSU and
Masayoshi MATSUSHITA

Department of Orthopedic Surgery, Okayama University Medical School

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Beyond a certain fixed period of time after an injury it becomes impossible to suture such an injured tendon, and consequently the tendon graft is required under such circumstances. When the tendon of a finger is injured, especially in no man's land, it is well known that the tendon graft is performed not only in the case of secondary repair but also of primary repair.

In performing the tendon graft it is important to bear in mind that the grafting should not be done undiscriminatingly anywhere in the damaged area. In other words, the graftable area of tendon should be determined according to the very nature of each case. Therefore, it must be performed in such a region where it would not interfere so much with the tendon movement as the palm of hand, the forearm, or the region surrounded mostly by soft tissues should be selected, where a slight adhesion may result (as there naturally occurs a certain degree of adhesion anywhere), but it would not interfere with the tendon movement. It is also important to suture the tendon at the site where the sutured part would not become involved with the tendon sheath of the finger or with the narrow part within the carpal tunnel when the tendon moves itself by its excursion. Thus when a tendon is to be grafted to the flexor tendon, three possible site of graft can be pointed out, namely, a site between the tip of a finger and the center of the palm, the site between the center of the palm and forearm, and the tip of a finger and the forearm. Moreover, in the case of the grafting tendon in thumb it would be better to do it in the entire length from the tip of thumb to the forearm.

Next, as for the prerequisites for the tendon graft it is needless to say that the skin should be normal and healthy and joints are involuntarily bendable. In case there is a scar in the vicinity of the joint or of the site where tendon is to be sutured, the prior skin graft is indicated ; and if the joints are rigid, the rigidity must be eliminated by the use of various splints or by capsulectomy and arthroplasty before grafting tendon.

In the following are presented the methods of our own, devised for the tendon graft in the fingers that we encounter most frequently.

METHODS

1. *The incision of the skin :* As for the incision of the skin at the time of tendon graft there are BUNNELL's[1], PULVERTAFT's[2], RANK-WAKEFIELD's[3] incision methods and each of them has its own advantage and disadvantage, and we perform our grafting in the manner as shown in Fig. 1. By this method the whole skin of the finger up to the palm is cut open in a flap form in the case of the index finger and small finger ; and for the middle and ring finger the whole skin of finger is flapped out, so that the extent of operation is wide and it is easy to observe the conditions of the damaged parts of tendon, the degree of adhesion and any damage to pulley, and in addition, the operation is easy and reliable. The skin flap is opened as shown in Fig. 2, leaving nerves below so that there is no danger of injuring the digital nerves. Moreover, because such a

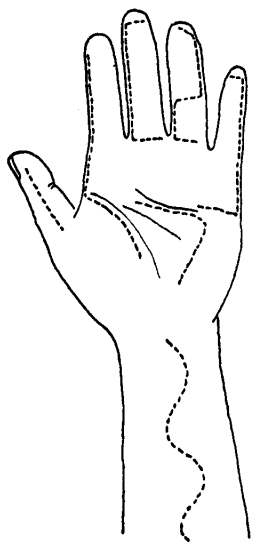


Fig. 1. Incision at the time of tendon grafting (dotted lines indicate the lines of incision)

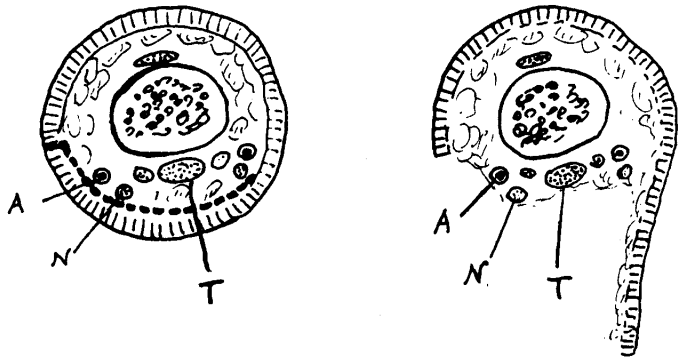
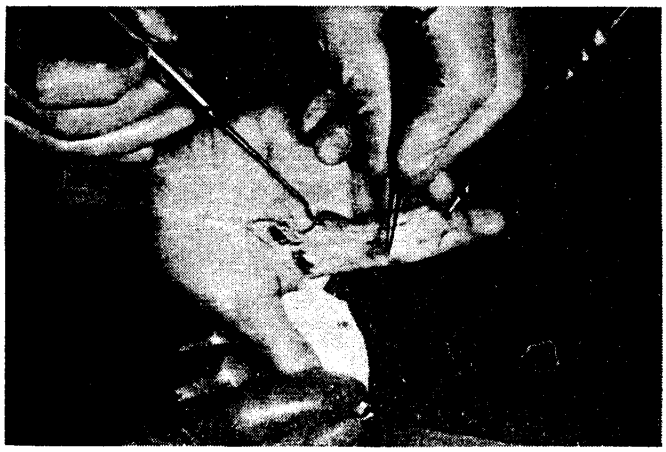


Fig. 2. The Ablation of the skin—Method of reaching tendon
A : artery N : nerve T : tendon

nerve is often injured at the time of the injury to tendon, our method of incision facilitates to a large extent the locating, observing, the suturing of the injured parts of the digital nerve.

Next, in the removal of the palmaris longus tendon to be used for the grafting the incision is made in the center of the flexor side of forearm in an undulating form and the care is exercised so that the tendon is taken out with as much paratenon as possible.



Eig. 3. Exposure of the tendon by flapping the skin open

2. *The removal of the tendon to be grafted :* Although various tendons are used for the grafting, we make it a rule to use the tendon of palmaris longus in the case where a single tendon is required, and the tendon of extensor digitorum longus of lower limb in the case where several tendons are needed. The reasons for our selecting of these tendons lie in that they are relatively thin and comparatively quick in securing proper circulation and that they can be removed with sufficient amount of paratenon attached. On the other hand, as the tendon of flexor digitorum sublimis is rather too big and the amount of fatty areolar tissue covering is too scanty, we do not use this tendon except in special case. Furthermore, in removing the tendon of palmaris longus the tendon is examined thorougly whether it has any cogenital defect and the appropriateness of its size according to each case before commencing operation. Again, in the case where long tendons of extensor digitorum longus need to be taken out extensively from the leg, it is necessary to separate each tendon carefully so as not to damage the surrounding tissues because the proximal side of the tendons are often connected with one another near

the crural curciate ligament. Even after the extraction of many tendons of extensor digitorum longus the functions of toes are hardly impaired because of the action of remaining flexor digitorum brevis.

3. *The importance of paratenon :* It is well known that the key to a successful graft of tendon lies in grafting tendon with a sufficient amount of healthy paratenon, and actually during grafting tendon is observed moving freely in paratenon. And after grafting even if paratenon should have adhered to the surrounding tissues, tendon is free to move ; but in the absence of paratenon the grafted tendon adheres to the surrounding tissues, thus imposing a great burden on the mobility of the tendon. For this very reason we remove atraumatically a tendon with a sufficient amount of paratenon attached by making a large undulating incision on the forearm. Fig. 4 shows the manner how the tendon of palmaris longus is being removed. Likewise in removing the tendon of extensor muscle in lower limb, it is essential to extract the tendon with sufficient paratenon.

Fig. 4. Removal of the tendon of palmaris longus

4. *The suturing of grafting tendon :* In the case of grafting tendon in a finger, there are many problems as regards the question whether the distal side should be sutured first and then the proximal side, or vice versa. This question arises because actually the grafting tendon should be given a certain fixed tension before suturing. It is the question to be decided by the ease with which such a desired tension may be attained in either case, but up to the present generally the distal side is sutured first, and then under a fixed tension the proximal side is sutured. However,

even this method of the suturing harbors some questions. We present here the description of the method recently devised by us, which enables us to attain a desired tension freely with ease by suturing the proximal side first, and which we consider to be quite useful.

(a) *The suturing of the proximal side* : The suturing of the proximal side of the grafting tendon seems to be better performed at the point where the lumbrical muscle is attached. At this point there is not much danger of impeding the tendon movement because of abundant soft tissues all around even if the adhesion should occur with the surrounding tissues. There is also another advantage in that the adhesion with the adjacent tissue can be kept at minimum when the sutured portion is covered with the lumbrical muscle.

As for the methods of suturing there are the pull-out method and the embedding method by Bunnell, Mason-Allen's method, Pulvertaft's method, Mortise method, and Iselin's method and all of which have their advantage and disadvantage ; but recently we are using BUNNELL'S[1] embedding method by suturing with wire as shown in Fig. 5, and we consider it quite convenient.

Coming to the covering of the sutured part by lumbrical muscle, as a rule we cover up the sutured portion gently as to avoid any undue tension on the muscle as can be seen from Fig. 6. However, we do not consider this as an absolute requisite. It is nevertheless absolutely necessary to avoid a high tension on the muscle at the time of suturing because sometimes it is liable to elicit the scar-formation on the lumbrical muscle and to increase the probability of adhesion.

(b) *The suturing of the distal side :* There are various methods for suturing of the distal side, but they can be roughly divided into two, namely, the one the suturing by embedding in the distal phalanx, and the other, suturing to the short cut-end of the flexor digitorum profundus tendon left in the finger.

As for the method of fixing onto the cut-end of tendon, there are Bunnell's pull-out method, embedding method, and their modifications, these methods have their short-comings in that the fixing is uncertain and there is another disadvantage of possible adhesion occurring between the distal interphalangeal joint and the sutured portion of tendon when the cut-end of tendon is left longer for the purpose of an easier manipulation.

Next, as for the fixing in the distal phalanx there are BUNNELL'S pull-out method, Fig. 7-A, Pulvertaft's method, Fig. 7-B, and our method shown in Fig. 8. Namely, by making a cross-wise incision on the dorsal side of distal phalanx about half way between the nail bed and the inter-

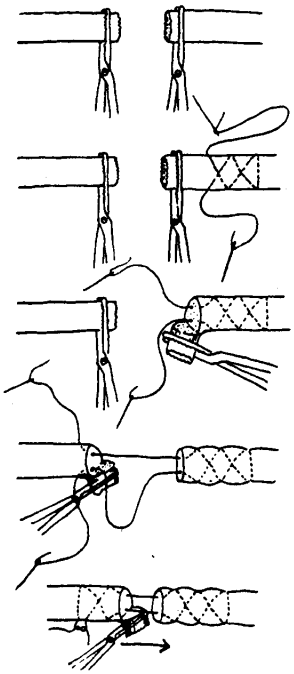


Fig. 5. The suturing of tendon by Bunnell's embedding method

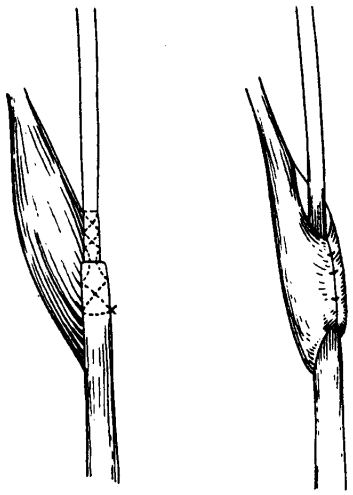
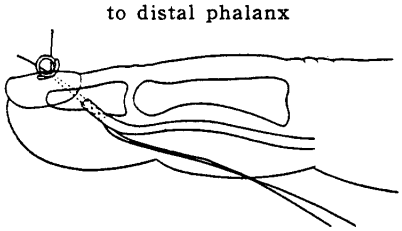


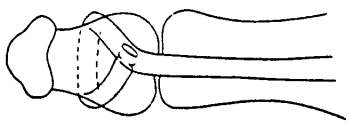
Fig. 6. The sutured portion of tendon covered by lumbrical muscle

phalangeal joint taking care not to injure the nail bed, two holes are drilled by a bone-drill slanting from the site of the palm side of the distal phalanx selected for fixing of grafting tendon in the direction of the incision made on the dorsal side of distal phalanx. Then the end of the tendon is split into two to a proper length and each of them is pulled out on the dorsal side of the finger by passing it through the drilled holes.

Fig. 7. The fixing of grafted tendon to distal phalanx



A. Pull-out method of Bunnell



B. Pulvertaft's method

Fig. 8. Fixing of tendon to distal phalanx by our method

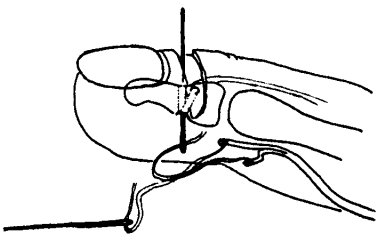
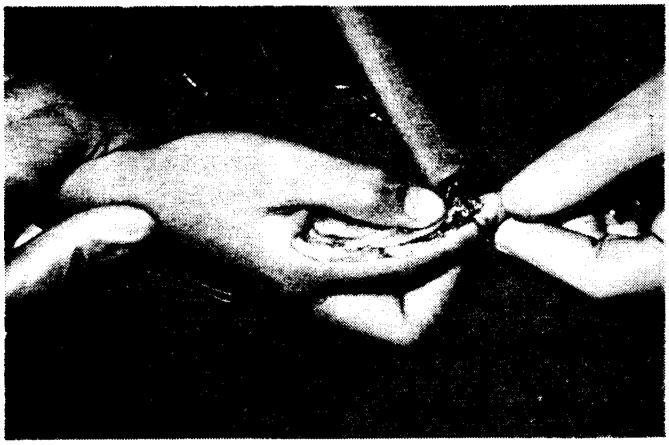
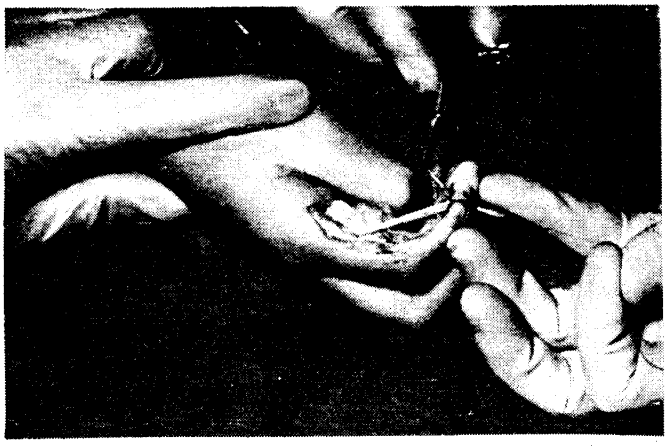


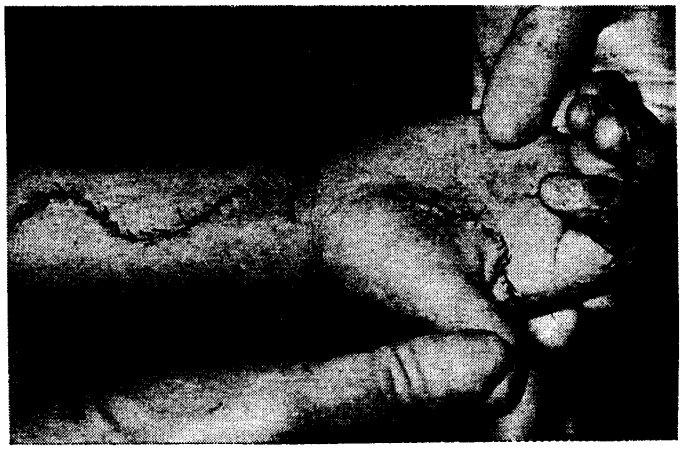
Fig. 9. Grafting tendon by our method



A. Drilling holes in distal phalanx



B. Passing two split ends of tendon through holes



C. Completely sutured

Here is an advantage of giving the grafting tendon just a desired tension at will by pulling the two split ends of the tendon and also of making the fixation more reliable. Although there are some short-comings in that it is difficult in the case of an infant with a small distal phalanx and the manipilation is more complex, but in reality it is not so difficult. There is another advantage in that the manipulation following the fixation of tendon can be carried out without fear because of the reliable fixting. Needless to say that it is of utmost importance to pay a special attention to the site of holes to be drilled so as not to injure the bone itself, joint or the nail bed by careless drilling.

It is also obvious that the grafting should be performed with the tendon of flexor digitorum profundus only, and as a matter of principle the tendon of flexor digitorum sublimis is excised in order to prevent the cross union.

5. *The degree of the tension on the grafted tendon :* In grafting tendon, it is necessary to give an appropriate tension on each tendon. As for the position of fingers at the time when they are completely relaxed and in rest position, it will be seen that the bending of the index finger is intermediate, and the degree of such a bending increases from the index finger to the small finger. This signifies that each finger always maintains fixed degree of tension, and also that this may be thought to indicate the normal tension of finger under normal condition. Therefore, it is naturally most appropriate to perform the tendon graft in such a way as to have the finger to assume this normal position after the suturing of tendon.

However, since the contraction of muscle can not be considered to be eliminated at once by the suture of tendon, just as much more tension must be given to the tendon as to compensate the recession in the muscle tension. It follows then that the position of a finger after the suture needs to be a little more tense than that at the rest position. Thus for obtaining just such an appropriate tension, by our method the proximal side is sutured at first and then by pulling the distal ends out on the dorsal side of the finger, it is possible to give at will the tendon just such a desired tension as already mentioned. In this instance it is better to bear in mind that the tendon needs generally be sutured a little more tense rather than less tense. Furthermore, even if the suture is made what appears to be a little more tense, the tension of the tendon after suture is often found to be of just a suitable degree. One must remember that for finger the bending is more important than stretching.

6. *The preparing of pulley :* In the case of an injury to the flexor

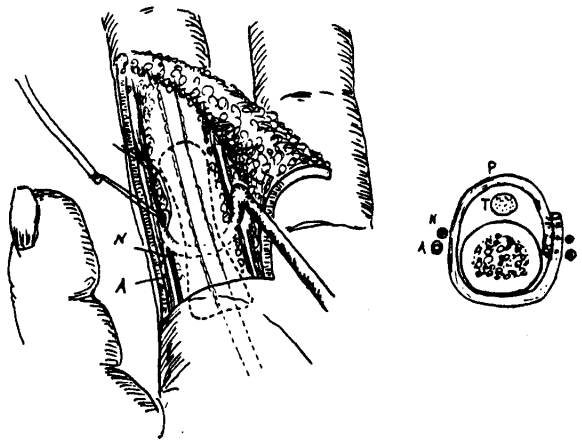


Fig. 10. Preparation of pulley

P : pulley N : digital nerve
A : digital blood vessel T : flexor tendon

tendon the tendon sheath attached to th proximal and middle phalanges is more often than not injured at the same time. In such a case as a rule the damaged sheath is excised and a pulley is installed in its place. If no such a pulley is installed, a complete bending of the finger can not be hoped for inasmuch as the tendon moves towards the flexor side at bending. At this juncture the sheath on the middle phalanx is not so essential, and if this sheath remains intact, the care should be taken not to injure it, but if it is damaged, it should be removed. However, the sheath on the proximal phalanx is particularly important, if it is damaged, it should be replaced with a new pulley.

As for the methods of preparing pulley, there are one that uses the fascia and another that uses tendon, but in preparing the pulley, it should be installed as near the metacarpo-phalangeal joint as possible, as it is said that the further away it goes from the metacapo-phalangeal joint the greater is the impediment on the movement of finger. From our experiences it is more convenient and satisfactory to use tendon (Fig. 10). All required is to make a ring of tendon around the proximal phalanx with Deschamp's needle. More recently we try to make a pulley in the manner as shown in Fig. 11. By this method not only the fixation is certain but also there is no danger of the damages such as aponeurosis. When operating with a wider field of vision by flapping the skin open, nerves, blood vessels and aponeurosis can be avoided that there is hardly any danger of causing any damage to them. However, when drilling

hole in the proximal phalanx an utmost care must be exercised. And the pulley should be made small but strong, and it should not be loose as there is a general tendency to make such, otherwise there is no meaning in making a pulley.

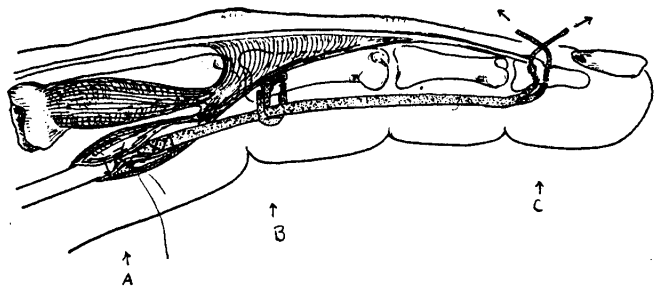


Fig. 11. Tendon graft in the finger by our method
A : sutured part of tendon
B : pulley in position
C : fixing tendon to distal phalanx

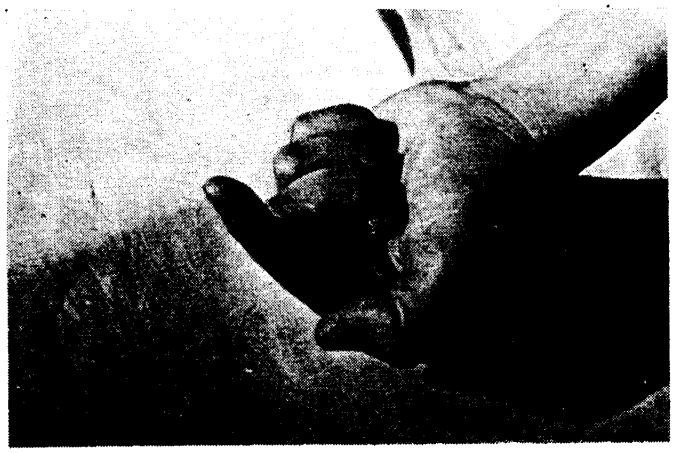
There is of course a question whether the installation of a pulley might not impede the mobility of tendon, but theoretically there is no way to restore a perfect bending of the injured finger other than installing a pulley. Therefore, it seems that obviously the use of pulley must be resorted to, but it must be prepared atraumatically.

7. *Post-operative care :* After grafting the hand and finger are moderately bent and fixed with compression bandage and splints, keeping the hand at the elevated position. The bandage is removed two weeks after operation and threads are pulled out then. Thereafter using vibra bath, free movement is commenced. Three weeks later and there on gradually more concerted exercire is prescribed.

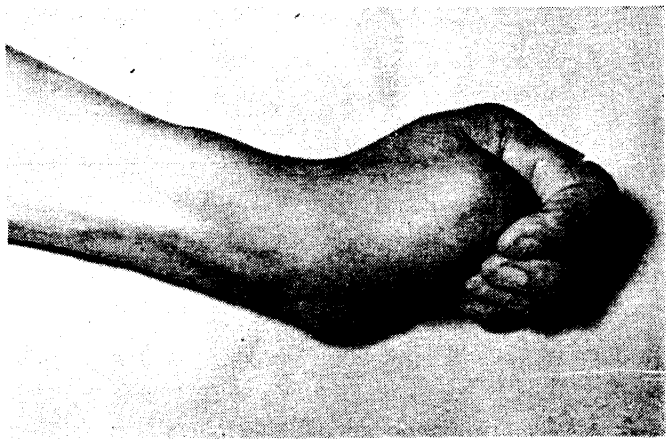
SUMMARY

In the foregoing our methods of the grafting of tendon in finger used recently are presented. Namely, the proximal ends of tendon to be grafted are at first sutured by the embedding method of BUNNELL[1], and then the distal ends are fixed with our method we get the benefits of giving just appropriate tension to the tendon and also of reliable fixation. Finally the findings before and after operation on the two cases treated by our method are pictorially presented in Figs. 12 and 13.

Fig. 12. Girl, 15 yrs. old, severed the flexor tendon of index finger at the metacarpo-phalangeal joint, 9 mos. previously, and grafted with tendon of palmaris longus, pulley used.

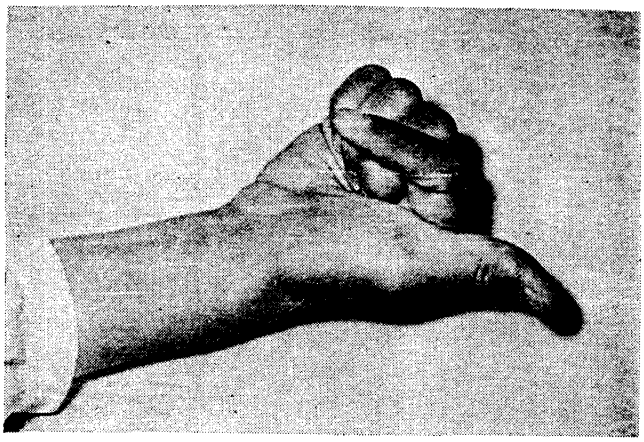


A. Before operation



B. After operation

Fig. 13, Girl, 11 yrs. old, severed the flexor tendon of index finger at the proximal interphalangeal joint, 1 mo. previously, and grafted with tendon of palmaris longus, without pulley.



A. Before operation

B. After operation

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